

**Title:** Experimental studies of phase equilibria of meteorites and planetary bodies.  
**Type:** Final Summary of Research Report  
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**Final Report for NASA Grant No. NAG5-10423**

In accordance with post-award requirements outlined in Title 14 CFR 1260.75, we submit a final report for NASA grant number NAG5-10423. There are four final report responsibilities. Three of these were submitted under separate cover and we provide only confirmatory language. A Final Research report is included herein.

**(1) Subject Inventions:**

No "invention" within the meaning of Title 39 CFR 401.2(c) were or will be produced as a result of work performed under this contract.

**(2) Final Federal Cash Transactions Report:**

A Final Federal Cash Transactions Report SF 272 was submitted in accordance with provision 1260.26(c).

**(3) Research report:**

**Overview**

The primary theme of this project was the application of experimental petrology and geochemistry to a variety of problems in meteoritics and planetary geology. The studies were designed to help develop constraints on the histories of primitive meteorites and their components, the environments in which they formed and evolved, and to understand quantitatively the processes involved in the evolution of igneous rocks on the earth and other planetary bodies.

We undertook several projects relating to the origin of CAIs and chondrules. Systematics in the thermodynamic properties of CAI-like liquids were investigated and used to elucidate speciation of multi-valent cations and sulfide capacity of silicate melts and to constrain redox conditions and the vapor pressures of volatile species over molten chondrules. We experimentally determined vanadium speciation in meteoritic pyroxenes

and in pyroxenes crystallized from CAI-like melts under very reducing conditions. We also found that bulk oxygen isotope compositions of chondrules in the moderately unequilibrated LL chondrites are related to the relative timing of plagioclase crystallization. We completed an experimental study on the vaporization of  $\beta$ -SiC and SiO<sub>2</sub> (glass or cristobalite) in reducing gases and established the conditions under which these presolar grains could have survived in the solar nebula.

We expanded our technique for determining the thermodynamic properties of minerals and liquids to iron-bearing systems. We determined activity-composition relationships in Pt-Fe, Pt-Cr and Pt-Fe-Cr alloys. Results were used to determine the thermodynamic properties of chromite-picrochromite spinels including the free energy of formation of end-member FeCr<sub>2</sub>O<sub>4</sub>. We also established a new approach for evaluating Pt-Fe saturation experiments. We calculated the T-fO<sub>2</sub> relationships in equilibrated ordinary chondrites and thereby constrained the conditions of metamorphism in their parent bodies.

References to abstracts and peer reviewed publications are presented below.

### Publications

- Beckett J.R. (2002) Role of basicity and tetrahedral speciation in controlling the thermodynamic properties of silicate liquids, part I: The system CaO-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>. *Geochim. Cosmochim. Acta*, **66**, 93-107.
- Kessel R., J.R. Beckett, and E.M. Stolper (2001) Thermodynamic properties of the Pt-Fe system. *Amer. Mineral.*, **86**, 1003-1014.
- Kessel R., J.R. Beckett, and E.M. Stolper (2003) Experimental determination of the activity of chromite in multicomponent spinels. *Geochim. Cosmochim. Acta*, **67**, 3033-3044.
- Kessel R., J.R. Beckett, G.R. Huss, and E.M. Stolper (2004) The activity of chromite in multicomponent spinels: Implications for the T-fO<sub>2</sub> conditions of equilibrated H chondrites. *Meteoritics Planet. Sci.*, **39**, 1287-1305.
- Mendybaev R.A., J.R. Beckett, L. Grossman, E. Stolper, R.F. Cooper, and J.P. Bradley (2002) Volatilization kinetics of silicon carbide in reducing gases: An experimental study with applications to the survival of presolar grains in the solar nebula. *Geochim. Cosmochim. Acta*, **66**, 661-682.

### Abstracts

- Beckett J.R. and E.M. Stolper (2001) Constraints on the evolution of chondrules based on the moderately volatile elements sulfur, sodium, and potassium. *Lunar and Planet. Sci.* **XXXII**, Abstr. # 1730.
- Beckett J.R. and Connolly H.C. (2002) On the use of phase and bulk compositions in classifying chondrules from Semarkona (LL3.0) and other ordinary chondrites. *Lunar and Planetary Science* **XXXIII**, Abstr. # 1547.

- Kessel R., Beckett J.R., and Stolper E.M. (2002) The thermal history of equilibrated ordinary chondrites and the relationship between textural maturity and temperature. *Lunar and Planetary Science XXXIII*, Abstr. # 1420.
- Matzen A., M.B. Baker, and J.R. Beckett (2004) Fe-Mg partitioning between olivine and high-magnesian melts: One-atmosphere experiments on a synthetic Hawaaiian picrite. *Eos*, in press.
- Sutton S.R., Simon S., Grossman L., Delaney J.S., Beckett J.R., Newville M., Eng P. and Rivers M. (2002) Evidence for divalent vanadium in Allende CAI fassaite and implications for formation conditions. *Lunar and Planetary Science XXXIII*, Abstr. # 1907.

**(4) Final Inventory Report of Federally Owned Property:**

No special or general purpose equipment with a fair market value exceeding \$5,000 was purchased with funds under this contract. A negative declaration to this effect was submitted.